Turbulent drag reduction with streamwise travelling waves in compressible regime

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The capability of streamwise-travelling waves of spanwise velocity to reduce turbulent skin-friction drag is assessed in the compressible regime. Several direct numerical simulations are used to compute drag reduction in subsonic, transonic and supersonic channel flows, and to compare with the incompressible case to extend previous works on oscillanting walls[1] and stationary waves[2]. Compressibility improves the favourable effect of the travelling waves, in a way that depends on the control parameters: drag reduction becomes larger than the incompressible one for small frequencies and wavenumbers. However, the quantification of the improvement depends significantly on the specific procedure employed for comparison. We propose two strategies. The former defines the Mach number based on the wall temperature, keeps it constant between the uncontrolled and controlled cases, whereas the bulk temperature in the flow is allowed to evolve freely in time until aerodynamic heating is balanced by the heat flux at the walls (fig.1 left); the latter defines and keeps constant the Mach number based on the the bulk temperature, which is constrained in time such that the same percentage of kinetic energy is transformed into thermal energy at the wall (fig.1 right). We provide arguments to support the view that, at least in the present context, the latter approach should be preferred. Not only it provides a test condition in which the temperature profile is a more realistic representation of that in an external flow, but also leads to a much better scaling of the results.

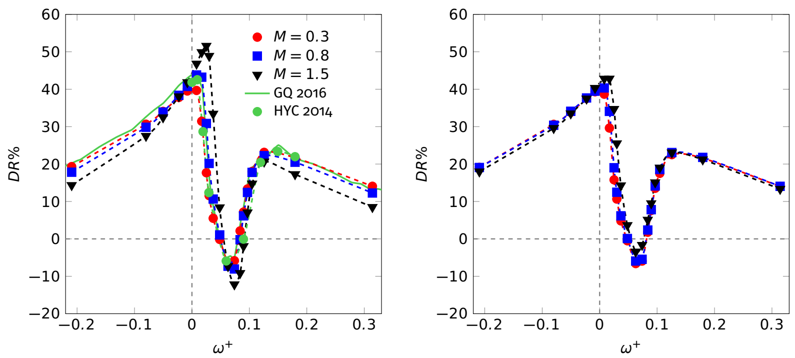

Figure 1: Drag reduction rate versus frequency ω^+ for the streamwise-travelling waves at $A^+ = 12$ and $\kappa^+ = 0.005$ at $Re_\tau = 400$ with the two different strategies. Incompressible reference data are in green.

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[1]Yao and Hussain, *J. Fluid Mech.* **5**, 8 (2020).
[2]Ruby and Foysi, *GAMM-Mitteilungen* **45**, 1 (2022).